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Impact of Lipid Peroxidation and Antioxidants on Nursery Pig Performance and Health[1]

Introduction

To increase energy density and improve feed efficiency, supplemental fats and oils (lipids) are commonly added to swine diets. Corn oil and other highly unsaturated lipids are susceptible to oxidation, adversely impacting lipid quality through the formation of free radicals, hydroperoxides and other oxidation products. Studies have shown fats and oils degraded by oxygen (peroxidized lipids) decrease performance of swine[2] and broilers[3] and cause oxidative stress. Oxidative stress creates an imbalance between the production of reactive oxygen species (ROS) and the biological ability to clear reactive intermediates. As ROS accumulate, damage to DNA, proteins and lipid components of cells can result.[4] Therefore, the addition of antioxidants in these conditions may be particularly critical.

Materials and Methods

For this trial, researchers assigned 176 pigs (9.1 kg initial body weight) to four treatment groups and housed the pigs in pens. Each pen held four (4) pigs, and pens were assigned to one of four (4) dietary treatments. Pigs were fed a corn and soybean meal-based diet in two phases – one from day (d) 1 to d14, and a second from d15 to d31 (Table 1). Diets were supplemented with 6% corn oil (oxidized or non-oxidized), with or without antioxidant (ENDOX® Dry) supplementation.

Treatments and Sampling. Treatment diets, manufactured at the North Carolina State University (NCSU) feed mill (Raleigh, NC), consisted of corn-soybean meal supplemented at 6% with control corn oil or corn oil that was intentionally peroxidized (Table 1). Oil was peroxidized by heating at 80°C, 15.4mL O2 /min per kg of lipid for 12 days. Analysis of the composition of control and oxidized corn oil is outlined in Table 2. Diets were supplemented with or without ENDOX Dry (0.4 lb/ton). Table 3 shows the compositional analysis of each of the four experimental diets. Blood samples were collected from 2 pigs per pen at day 2, at day 16 and day 31 (end of the trial) to determine oxidative status by measuring malondialdehyde (MDA) and vitamin E levels in serum.

Table 1. Composition of experimental diets (as fed basis)

Ingredient, %	Phase 1	Phase 2
Corn, yellow dent	57.56	60.23
Soybean meal, 47.5% CP	33.10	30.71
Corn oil[1]	6.00	6.00
L-lysine HCl	0.37	0.35
DL-methionine	0.16	0.11
L-threonine	0.14	0.09
Monocalcium phosphate, 21% P	0.83	0.75
Limestone	1.13	1.05
Salt	0.50	0.50
Phytase	0.016	0.016
Vitamin premix	0.04	0.04
Trace mineral premix	0.15	0.15
Antioxidant[2]	0/0.125	0/0.125

[1]Control or peroxidized corn oil
[2]Added to half of experimental treatments; ENDOX® Dry; Kemin Industries, Inc.

Table 2. Analyzed composition of oxidized and control corn oils.

	Control	Peroxidized
Moisture, %	0.5	0.5
Insoluble Impurities, %	0.13	0.10
Unsaponifiable Matter, %	0.78	0.56
Free Fatty Acids, %	0.09	0.11
Iodine Value	123.2	116.9
Peroxide Value, mEq/kg		
Initial	0.4	146
4h AOM	3	290
20h AOM	443	539
Anisidine Value	2.2	164.4
Oxidative Stability Index (OSI), h	20.63	2.95
Hexanal, ppm	<10.0	345
2,4-Decadienal, ppm	7	1622
Total Fatty Acids, %	93	90.2

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Analyses. Data was analyzed using PROC Mixed of SAS (v. 9.4; SAS Inst. Inc., Cary, NC) testing for fixed effects of time of sampling, peroxidation, antioxidant and relevant interactions. Pig nested within pen was used as random effect. Mean values were compared by Tukey-Kramer test. Pens of pigs were weighed and feeder measurements taken at days 1, 14, and 31. This data was used to determine ADG, ADFI and G:F.

Table 3. Analyzed composition of experimental treatment (as fed basis)

	Control		Peroxidized	
	No Antioxidant	Plus Antioxidant	No Antioxidant	Plus Antioxidant
Moisture, %	12.77	12.69	12.93	12.68
Crude Protein, %	19.44	19.64	19.71	19.82
Crude Fat, %	8.35	8.62	8.51	8.64
Calcium, %	0.68	0.71	0.73	0.74
Phosphorus, %	0.51	0.54	0.54	0.52
Ethoxyquin, ppm	<10	26.5	<10	16

Results and Discussion

As expected with a short 31-day trial, an immediate performance benefit following the utilization of an antioxidant was not shown statistically (Table 4). Unlike the long-term effects of low-level oxidized lipids, short-term exposure didn't overwhelmingly impact average daily gain (ADG), average daily feed intake (ADFI) or gain:feed (G:F).

However, even in a research setting with little-to-no stress on the animals, a significant impact was seen in the serum vitamin E concentration when including the antioxidant ENDOX Dry, which overtime can show deleterious effects of low vitamin E available due to consumption as a biological antioxidant (Fig. 1). Inclusion of ENDOX Dry at 0.4 lb/ton to non-oxidized feed demonstrated a 0.36 ppm increase in serum vitamin E levels over the non-treated, non-oxidized feed. In the presence of oxidized feed, the ENDOX Dry treated feed provided a 0.17 ppm serum vitamin E increase.

Table 4. Pig growth performance, feed efficiency and mortality.

	Control		Peroxidized			*P*-VALUE		
	No Antioxidant	Plus Antioxidant	No Antioxidant	Plus Antioxidant	SEM	*Peroxidation*	*Antioxidant*	*Interaction*
Initial BW, kg	9.11	9.11	9.11	9.11	0.428	0.940	0.985	1.000
Day 14 BW, kg	12.88	12.64	12.81	12.57	0.643	0.814	0.414	0.989
Final (d 31) BW, kg	24.21	25.11	24.13	24.05	0.89	0.153	0.298	0.216
Phase 1 ADG, kg	0.244	0.222	0.221	0.227	0.025	0.502	0.883	0.654
Phase 2 ADG, kg	0.632	0.666	0.577	0.648	0.047	0.341	0.154	0.277
Total ADG, kg	0.486	0.489	0.470	0.481	0.022	0.433	0.628	0.770
Phase 1 ADFI, kg	0.459	0.498	0.472	0.455	0.025	0.915	0.746	0.596
Phase 2 ADFI, kg	1.023	1.097	1.017	1.033	0.037	0.149	0.070	0.238
Total ADFI, kg	0.760	0.817	0.762	0.763	0.041	0.213	0.165	0.177
Phase 1 G:F	0.521	0.466	0.430	0.490	0.045	0.356	0.944	0.454
Phase 2 G:F	0.519	0.487	0.461	0.492	0.036	0.135	0.096	0.561
Total G:F	0.502	0.452	0.462	0.473	0.024	0.801	0.333	0.104
Mortality, count	3	6	6	3	-	1.000	1.000	0.526

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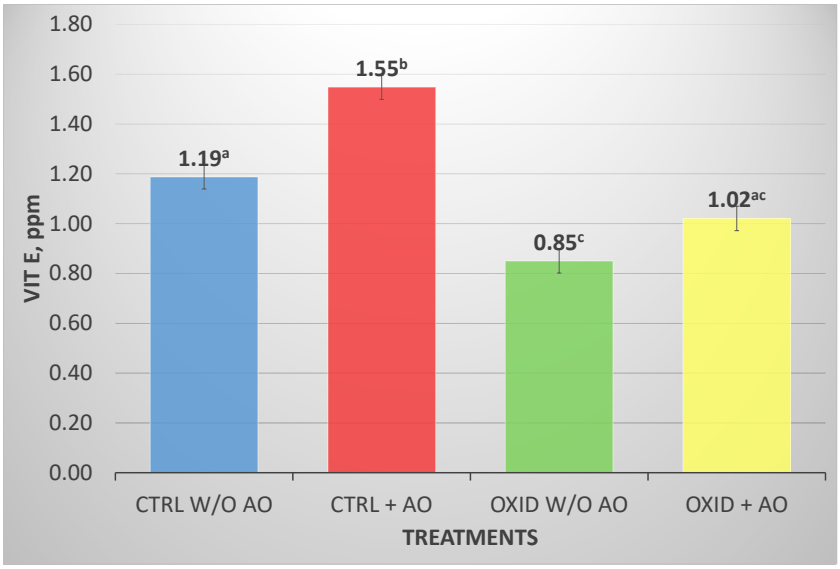

Figure 1. Serum vitamin E concentration[1] measured at day 31 from pigs fed dietary treatments. Treatment groups included: control corn oil without antioxidant supplementation (CTRL W/O AO), control corn oil with antioxidant supplementation (CTRL + AO), peroxidized corn oil without antioxidant supplementation (OXID W/O AO) and peroxidized corn oil with antioxidant supplementation (OXID + AO). Values are expressed as mean ± standard error mean (SEM). [1]Main effect of antioxidant ($P < 0.001$). [a-c]Means without a common letter tended to differ (oxidation x antioxidant interaction; $P < 0.06$).

Conclusion

Research has shown the bioavailability of vitamin E in pigs has a direct impact on many biological systems including immune, digestive and reproductive systems. Low levels of circulating vitamin E has been linked to many disease conditions in swine including mulberry heart disease, which is manifested by an accumulation of fluid in the pericardial sac and sudden death.[5] Common practice, in many swine diets, includes the supplementation of vitamin E to ensure optimum health and production performance. However, even with supplementation, vitamin E deficiencies are still common due to the relatively poor absorption of vitamin E due to degradation or competition from other feed ingredients. When investing in vitamin E supplementation it is critical that the active vitamin E compounds are absorbed and distributed to the body tissue to ensure effectiveness. Utilizing ENDOX Dry antioxidant can be an effective means to aid in the increase absorption of vitamin E in the muscle tissue, which can positively impact overall pig health.

References

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